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A bottom-up strategy for establishment of EER in three Nordic countries – the role of networks

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Abstract

This paper investigates the emergence of an engineering education research (EER) community in three Nordic countries: Denmark, Finland and Sweden. First, an overview of the current state of Nordic EER authorship is produced through statistics on international publication. Then, the history of EER and its precursor activities is described in three national narratives. These national storylines are tied together in a description of recent networking activities, aiming to strengthen the EER communities on the Nordic level. Taking these three perspectives together, and drawing on concepts from community of practice theory, network theory and learning network theory, we discuss factors behind the differences in the countries, and draw some conclusions about implications for networking activities in a heterogeneous community. Further, we discuss the role of networks for affording a joint identity.

Keywords: engineering education research; research networks; community building; Nordic engineering education research

1. Introduction

In this article, we will describe and analyse the development of engineering education research (EER) throughout the last 30 years in three Nordic countries: Denmark, Finland and Sweden. In this region, a series of initiatives and networks have been established on the individual, institutional, regional, and international levels. Our aim is to give an overview of the development and analyse different strategies for strengthening the EER community, hoping to learn from the Nordic history and point at future directions. The underlying questions are: what factors can be identified as particularly influential behind the development of EER in the three Nordic countries, what initiatives have been taken, and, in particular, what was the role of regional and international networks and communities?

The reason for focusing on networks and communities is that these have played a particularly important role in furthering a European EER scene. In the United States the National Science Foundation has since the 1990's invested heavily in engineering education research, growing and supporting a community of researchers specialising in the field. Implicitly, the dependence on NSF created a need to increase academic legitimacy, and much American activity in EER networks has focused on a process towards discipline formation (Borrego & Bernhard, 2011; Jesiek, Newswander, & Borrego, 2009; Lohmann, 2008; Streveler & Smith, 2006). In the absence of a similar proactive funding source on the European level, any cohesive forces promoting EER in Europe have instead been created mostly through international, national and regional networks. Therefore, the development of European EER has been more fragmented and bottom-up, with roots in activities such as staff development, reform and educational development initiatives on different levels, didactics research in various disciplines, and higher education research. Funding sources are equally diverse, ranging from regular institutional research funding, special institutional support, and external project funding.

These differences in history and conditions might help explain some differences in interpretation of the goal and scope of EER communities. In Europe the EER societies have been more of meeting places for discussing issues in engineering education, while in US they were the locus for a conscious and collective movement to create and shape the academic field. It is also indicative how the leading engineering education journals in the US and Europe have adopted different roles, with the US-based Journal of Engineering Education taking a more academic approach (Felder, Sheppard, & Smith, 2005; Lohmann, 2008) while the European Journal for Engineering Education prioritises usefulness for practitioners (De Graaff, 2014).

2. Analytical framework

A useful theoretical framework for understanding the function and roles of academic networks is the theory of communities of practice (Wenger, 1999). In short, a community of practice (CoP) is a social formation with some kind of joint enterprise. Such communities develop a culture that signifies the community and provides a framework for what activities take place and how those activities are executed. The culture in a CoP is only to some extent explicitly expressed; much is tacit. Participants adjust to the culture and learn in interaction with the other members. This is a part of the process of being an active participant in the practice of a social community and also constructing an identity in relation to the community. Wenger identified four components for the process of learning in a social community:

- meaning – the way the members in the community talk about their abilities, and changes in their abilities,
- practice – how the members talk about their shared historical and social resources, frameworks, and perspectives,
- community – how members talk about the social framework for the common enterprise and how the members competencies relates to this,
- identity – how members talk about how learning changes how they are and the personal stories of becoming in this specific social context.

A network – just like a CoP - consists of various actors and the relations among the actors. The network theory (Snehota & Håkansson, 1995) characterises networks as the interplay of *actor bonds*, *activity links* and *resource ties*. This model highlights the conditions at various levels, by stating that activities will always be dependent on the resources (for instance human resources and funding). This perspective thus

complements the interpretation that can be made using the concepts associated with community of practice, as these mainly focus on sociocultural dimensions.

The learning network theory originates from organisational learning, and emphasises the formal and informal learning that will take place in every organisation (Poell, Chivers, Van der Krogt, & Wildemeersch, 2000). There are three main components in a learning network: the learning actors, the learning process and the learning structures (Van der Krogt, 1998). What is of particular interest in this theory is the characterisation of the interaction. Types of learning networks are defined by the organisational setting for the interactions (see Table 1). The four types of learning networks have different purposes and will develop different CoPs.

Table 1. Four theoretical types of learning networks. Adapted from Van der Krogt (1998).

	Liberal	Vertical	Horizontal	External
	Single activities	Linearly planned	Organically-oriented	Externally co-ordinated
<i>Learning processes</i>				
Development of learning policies	Implicit	Planning	Learning	Inspiring
Development of learning programmes	Collecting	Designing	Developing	Innovative
Execution of learning programmes	Self-directing	Guiding	Counselling	Advisory
<i>Learning Structures</i>				
Content structure (profile)	Unstructured (individually-oriented)	Structured (task-or-function-oriented)	Open or thematic (organization or problem-oriented)	Methodical (profession-oriented)
Organizational structure (relations)	Loosely coupled (contractual)	Centralized (formalized)	Horizontal (egalitarian)	Externally directed (professional)
Learning climate	Liberal	Regulative	Integrative	Inspiring

Equipped with these theoretical concepts this paper sets out to investigate the development of EER during the past 30 years in the three Nordic countries. We will mention the wider development in Europe and world-wide mainly when it has impacted the Nordic development, but it is outside the scope of this paper to investigate the role of EER networks in general, or to describe the development of EER world-wide (see for

instance Borrego & Bernhard, 2011). Our contribution to documenting the evolution of EER is to zoom in on this region applying a longitudinal perspective.

3. Methodology and limitations

In charting the history of EER in Sweden, Denmark and Finland, it was necessary to decide what work and activities to include in our data selection. It is open for interpretation what to regard as EER or a precursor for it. We have chosen to apply a sociological and empirical approach, focusing on actors who have been visible in the dominant EER communities, either through authorship or participation in projects and network activities. Within this heterogeneous group there are various degrees of identification as engineering education researchers, as well as different epistemological interpretations of what EER is; however this is outside the scope for this article.

When investigating the development over three decades, we find the early period far more difficult to trace. This is not simply because time has passed, or because we are studying an emerging field which has only gradually become more established. It is also because older work is often more local, less formalised in nature, and less formally documented. This is a transition period when academia shifted to a stronger focus on “production” at all levels, including publishing in formal journals, tracking publications, and external research funding. Globalisation and communication technology have transformed and intensified the modes of collaboration and publication – from printed media and telephone to interactive online collaboration and electronic publication with nearly open access to everything. Therefore, early material is seldom indexed, until the shift around 2000 towards online publication.

We have chosen to combine three different perspectives in the data collection: international publication, national narratives, and Nordic networking, each with its own timeframe and method for sampling data. Triangulating these different perspectives is

meant to provide a more comprehensive view. However, this paper does not claim to give a complete and unbiased picture. There will certainly be other journals, activities and researchers who did not participate in the arenas where our searchlight fell. Further, the three perspectives are to some extent overlapping and interdependent.

First, taking the *international publication perspective*, the aim is to provide a quantitative overview of the most active countries, individuals, and institutions. The weakness of this perspective is that most of the older material is not indexed, making it hard to retrieve a representative sample of early publications. Further, there is no generally agreed definition of what signifies an EER paper. Therefore it is not a clear-cut decision to classify papers as research papers in settings with many papers reporting experiences of teaching innovations, introducing novel educational technology tools, discussing curriculum issues, and position papers. For these reasons, our emphasis is on present-day publications already classified as EER. Different types of literature searches produced a statistical overview of Nordic authors in the European Journal of Engineering Education (2000-2014) as well as Nordic authors' contributions classified as EER in the recent SEFI conferences 2010-2014.

Then, in the *national narratives*, the aim is to identify activities, actors and resources on the national, cross-institutional, and institutional levels. Here, the timeline goes back to the early period with the help of leaders of national initiatives, one in Denmark and one in Sweden (both now retired). They were interviewed about their view on the history of EER, and later validated the written narratives. For the sake of brevity, the storylines are limited to a few highlights in each country. As the purpose was to trace the roots of present-day EER, the bias is towards initiatives that created some legacy or a lasting impression.

Finally, taking the *Nordic networking perspective*, we describe two Nordic networks that started in 2009, funded by the same source. One network organised a doctoral course in EER and the other organised regular networking meetings. These are conscious efforts to promote an EER community and to offer a common identity as engineering education researchers. The organisers, as well as most participants, come from Denmark, Sweden and Finland. This is also the main background to our selection of geographic scope for this paper, i.e. we did not include EER in Norway due to lack of visibility on the Nordic and European scenes.

Below, we start by presenting the pattern of international publication, thereby providing an overview of the present state of EER. After that, we recount the history of EER and its precursor activities in three national narratives. Finally, we continue the national stories by tying them together in the Nordic networking activities.

4. International publication patterns for Nordic EER

We have investigated publications from Nordic authors in two venues: the European Journal for Engineering Education (EJEE) and the annual SEFI conference. Both are well-established; in 2015 the SEFI conference was organised for the 44th time and EJEE published its 40th volume. We acknowledge that Nordic authors also publish papers elsewhere, but it was outside the scope of our resources to survey a wider pool. Both EJEE and SEFI are central from a European perspective, and especially from the Nordic point of view.

We included 15 years of EJEE papers published in 2000-2014 (volumes 25-39), a period when EER has been developing an identity as a research field. We excluded editorials, book reviews and similar, considering all remaining papers as full papers presenting original EER work. The EJEE data pool included 733 papers, of which 109 papers had at least one Nordic author, i.e., author with an affiliation in some university,

organization or company in Denmark, Finland, Norway or Sweden (no authors from Iceland were found).

The other data pool included SEFI conference papers from 2010-2014. The starting point does not imply that there were no EER papers in the conference earlier, but searching through the 2008-2009 proceedings we found very few papers with keywords “engineering education research” or likewise. 2010-2012 there was a special track for EER papers, allowing authors and program chairs to explicitly label some papers as research. In 2013 and 2014 the track structure was changed and we selected all papers with keywords “engineering education research” or similar. The SEFI data pool included 169 papers, of which 51 had at least one Nordic author.

Tables 2 and 3 present the papers and numbers of Nordic authors in more detail. As we can see, Finland has been most active in publishing papers in the SEFI conference, with Denmark and Sweden closely following. We did not find any papers from Norwegian researchers. On the other hand, Swedish authors are the largest group publishing papers in EJEE followed by Finland and Denmark. Norwegian authors are the smallest group publishing papers here. We found only a few papers as evidence of Nordic collaboration, 4 papers in SEFI and 6 papers in EJEE.

Table 2. SEFI papers with Nordic authors. Note that the total number of different authors in countries is not the sum of yearly counts, because each author is counted only once during the total period.

Years	2010	2011	2012	2013	2014	TOTAL
Papers in total	29	33	33	57	17	169
Papers with Nordic author	9	11	13	15	3	51
Papers with Danish author	4	4	4	5	1	18
Papers with Finnish author	4	5	7	6	1	23
Papers with Norwegian author	0	0	0	0	0	0
Papers with Swedish author	2	2	4	6	2	16
Papers with authors from two Nordic countries	1				1	2
Papers with authors from three Nordic countries			1	1		2
Total different authors						
Denmark	9	9	6	6	1	27
Finland	17	10	20	9	3	41
Norway	0	0	0	0	0	0
Sweden	5	3	5	9	2	16
Total different Nordic authors	31	22	31	24	6	84

Table 3. EJEE papers with Nordic authors, volumes 25 – 39 (2000 – 2014). Note that the total number of different authors in countries is not the sum of yearly counts, because each author is counted only once during the total period.

Volume	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Total
Papers	36	39	37	44	53	45	64	62	51	50	52	49	52	53	46	733
Papers with Nordic author	2	8	5	6	10	4	4	12	12	17	6	6	6	6	5	109
Papers with Danish author	0	4	0	0	6	0	1	3	4	3	1	2	3	2	2	31
Papers with Finnish author	0	3	0	3	2	3	1	5	2	6	3	2	0	4	1	35
Papers with Norwegian author	0	0	2	0	0	0	1	2	0	0	1	0	2	0	0	8
Papers with Swedish author	2	3	3	3	2	2	2	2	6	9	1	2	1	0	3	41
Papers with authors from two Nordic countries	0	2	0	0	0	1	1	0	0	1	0	0	0	0	1	6
Papers with authors from three Nordic countries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Different authors																
Denmark	0	8	0	0	7	0	1	5	9	7	2	3	5	6	2	40
Finland	0	4	0	5	2	9	3	7	4	10	5	5	0	8	1	53
Norway	0	0	2	0	0	0	1	4	0	0	1	0	3	0	0	7
Sweden	2	4	6	9	3	2	3	2	9	15	1	3	3	0	4	58
Total different Nordic authors	2	16	8	14	12	11	8	18	22	32	9	11	11	14	7	158

Table 4 presents the summary of both datasets, SEFI and EJEE. Since the Nordic countries have very different populations (Denmark 5.6, Finland 5.4, Norway 5.1, and Sweden 9.6 million people), the absolute numbers of papers and authors are not comparable across countries. In the final column the numbers are normalised according to population size, revealing that Finnish researchers are the most active in both venues, followed by Danish, Swedish and Norwegian researchers.

Table 4. Summary of SEFI and EJEE datasets, and the normalized counts. Note that the total number of different authors in countries is not the sum of both venues, because each author is counted only once.

Papers with Nordic author	SEFI	EJEE	Total	Papers / million people
Papers with Danish author	18	31	49	8,8
Papers with Finnish author	23	35	58	10,7
Papers with Norwegian author	0	8	8	1,6
Papers with Swedish author	16	41	57	5,9
Different authors				Authors / million people
Denmark	27	40	60	10,7
Finland	41	53	88	16,3
Norway	0	7	7	1,4
Sweden	16	58	69	7,2
Total different Nordic authors	84	158	224	8,7

There is clearly a peak of Nordic papers in EJEE in years 2007-2009 (vols. 32-34). This is partially explained by a few special issues. The special issue on “Educating Engineers for Sustainable Development” had several Swedish contributions. The issue “Educational research impacting engineering education” included 7 papers with Swedish authors, most dealing with qualitative research methods like phenomenography and variation theory, which have a strong tradition in Sweden. Several of these authors have no other papers in the EJEE dataset, which suggests that the special issue solicited new authors.

A closer look at the data sets revealed a scattered pool of EER researchers. Both data pools together include 60 author names from Danish institutes, 88 from Finland, 7

from Norway and 69 from Sweden, in total 223 different names.¹ Only 55 of these have authored more than one paper. The 12 most active authors, with at least 4 papers, are listed in Table 5.

Table 5. The most active authors in the data set.

Name	Affiliation	Papers (SEFI + EJEE)
Anette Kolmos	Aalborg University (Denmark)	10 (5 + 5)
Jonte Bernhard	Linköping University (Sweden)	9 (7 + 2)
Kirsti Keltikangas	Aalto U. / Helsinki U. of Technology (Finland)	8 (6 + 2)
Erik de Graaff	Aalborg University (Denmark)	6 (6 + 0)
Päivi Kinnunen	Aalto U. / Helsinki U. of Technology / U. of Eastern Finland (Finland)	5 (4 + 1)
Pirjo Pietikäinen	Aalto U. / Helsinki U. of Technology (Finland)	5 (5 + 0)
Lise Busk Kofoed	Aalborg University (Denmark)	4 (1 + 3)
Xiang-Yun Du	Aalborg University (Denmark)	4 (0 + 4)
Pia Lappalainen	Aalto U. / Helsinki U. of Technology (Finland)	4 (0 + 4)
Lauri Malmi	Aalto U. / Helsinki U. of Technology (Finland)	4 (3 + 1)
Anna-Karin Carstensen	Jönköping University (Sweden)	4 (3 + 1)
Michael Christie	Chalmers University of Technology (Sweden)	4 (0 + 4)

As can be seen in the table, some universities have been very active. Table 6 lists the most active universities, counting the number of papers with at least one author affiliated there.

¹ The sum is 224, but one author affiliation has changed.

Table 6. The most active institutions in the data set.

Institution	Papers (SEFI + EJEE)
Aalto University/Helsinki University of Technology/Helsinki University of Art and Design (Finland)	35 (20 + 15)
Aalborg University (Denmark)	31 (16 + 15)
Linköping University (Sweden)	15 (7 + 8)
Chalmers University of Technology (Sweden)	13 (3 + 10)
KTH Royal Institute of Technology (Sweden)	10 (2 + 8)
Lund University/Lund Institute of Technology (Sweden)	8 (3 + 5)
Technical University of Denmark (Denmark)	7 (1 + 6)
Uppsala University (Sweden)	7 (1 + 6)
University of Copenhagen (Denmark)	6 (2 + 4)
University of Oulu (Finland)	6 (0 + 6)

5. National narratives

5.1. *EER in Denmark*

5.1.1. *Early EER*

Denmark has a long history of engineering education research in universities, with some roots in nearby fields such as Science, Technology and Society Studies (STS). Research came in response to institutional needs, e.g. supporting the PBL model and mandatory staff development in teaching and learning. Denmark has had a strong national network that evolved with ties to Nordic and European communities.

In 1990, there were two universities offering engineering degrees on the master level (Technical University of Denmark, DTU, and Aalborg University, AAU) and seven technical colleges with engineering on a bachelor level. Since then, the technical colleges have been merged with existing universities or formed interdisciplinary institutions called university colleges (Christensen & Erno-Kjølhed, 2011).

At the two universities, EER dates back at least to the 1980's. At DTU, Arne Jakobsen formed a group at the Department for Social Science analysing engineering education (Arne Jakobsen & Anker Jensen, 1982; Arne Jakobsen & Jespersen, 1985) and Ulrik Jørgensen studied the work, competence development and career structure of engineers (Jørgensen, 1996, 1997). Aalborg University was based on a new pedagogical PBL model, and needed to document its effect. PhD degrees were given within engineering education and academic positions were announced (e.g. Anette Kolmos became assistant professor in EER in 1989). Here, similar to the history at DTU, EER grew out of the research group on Technology and Society and several reports were published on both the educational aspects as well as engineering graduates (Jensen & Wagner, 1990; Kolmos, 1989a, 1989b).

In 1993, Danish law made pedagogical training of assistant professors compulsory at universities, and both Aalborg and DTU established research-based pedagogical centres where staff had research and teaching positions. The activities were mainly pedagogical training, seminars, conferences, and research activities (Arne Jakobsen & Meleschko, 1999; Kolmos, Rump, Ingemarsson, Laloux, & Vinther, 2001). At Aalborg University, the Centre for University Teaching and Learning (PUC) involved researchers who were active in educational development. The first director came from the Faculty for Engineering and Science to an associate professor position in engineering education research. At DTU the Centre for Engineering Educational Development (CDM) was formed with the ambition to create a research environment "on the same level as the engineering disciplines" and several research projects were carried out (Arne Jakobsen, Rump, Clemmensen, & May, 1999). Eventually, the centre failed to sustain its legitimacy (Danmarks Evalueringsinstitut, 2003) and DTU discontinued EER activities. Some CDM researchers moved to science education

research at Copenhagen University, where there is work on innovation and technology (Holmegaard, Madsen, & Ulriksen, 2014). DTU reorganised the CDM activities, keeping the development and training in a new unit, the DTU Learning Lab. This coincides with DTU joining the CDIO Initiative as one of the first collaborators, and it has stayed a very active collaborator.

5.1.2. National networking and international ties

To support pedagogical training of academic staff also at the technical colleges, the Ministry of Education funded the Danish National Pedagogical Network for Engineering Education (IPN) during 1996-2008. All engineering education institutions in Denmark were included and the objective was to strengthen the development of the pedagogical and didactic quality. The focus was mainly on development on the individual academic and classroom level. One part-time person was funded at each institution, and supported by the network. Some core activities were curriculum development projects, conference and seminar activities together with other national stakeholders, national training courses for assistant professors in the technical colleges, a newsletter, and national and Nordic conferences (Vinther & Kolmos, 2002). Though research was not a formal objective of IPN, much work was published (for instance Andersen et al., 2006; Andresen, Thorslund, & Ingeniøruddannelsernes Pædagogiske Netværk., 2006; Støren & Aamodt, 2010). Some research activities connected with SEFI, and some formed Nordic bonds (Kolmos, Vinther, Andersson, Malmi, & Fuglem, 2004).

Networks are always facilitated by individuals, and Ole Vinther, associate professor at the Engineering College in Copenhagen, was a key person. It was a close collaboration between Ole Vinther, Anette Kolmos and Arne Jakobsen that formed the ground for the IPN. Ole Vinther also served in the Administrative Council in SEFI and

in the SEFI curriculum group. It was through SEFI that the contacts at the Nordic level were established. The international collaborations resulted in several SEFI conferences and other SEFI activities on Danish ground, and later Anette Kolmos was SEFI President. It is also worth noting that the American Society for Engineering Education (ASEE) was actively participating in SEFI meetings, promoting the EER coalitions that were established in the US during the 1990's.

In Denmark, the strategic research council funded in 2010-2014 a research alliance to examine how engineering educational institutions are responding to a series of societal and sustainability challenges. The alliance connected three research areas: engineering education research, engineering epistemology, and STS. This interdisciplinary meeting place aimed to synthesise new perspectives and provide a knowledge base for educational reform and institutional initiatives in engineering.

Today Aalborg University dominates Danish EER with two large research groups: the UNESCO Centre for PBL in Engineering, Science and Sustainability has a large group of national and international PhD students, and the Centre for Design, Innovation and Sustainability focuses more on the STS aspects. The Danish participants in the NNEER seminars are from these two research groups.

5.2. EER in Finland

5.2.1. Productive but scattered individuals

In Finland, higher technical education is organised in three technical and four comprehensive universities, and several polytechnics (also called universities of applied sciences). These two sectors have developed their educational strategies fairly independently, although local collaboration between a university and a polytechnic has been fruitful in several sites. EER work in Finland has been very much scattered. There

have been many initiatives to develop various areas of engineering education *practice* on institutional, multi-institutional or national level, as well as through many EU funded international projects. For instance, many Finnish institutions are active in the CDIO Initiative. However, these activities have seldom focused on engineering education *research*.

The Finnish EER field consists of a substantial number of individuals in many institutions. They involve teachers who have been developing education in their own field, from educational development units, or professional organizations. Our data set (SEFI 2010-2014, EJEE 2000-2014) includes 71 papers with Finnish authors, in total 88 different individuals affiliated to 15 different universities, polytechnics, organisations or companies. Most of them appear to have been working isolated from each other. In the data set, we found only 12 authors who had co-authored more than one paper with some specific colleague. Nine of these were from Aalto University or its predecessor Helsinki University of Technology (the other 3 researchers wrote just 2 papers together). Thus, Aalto University has been the only institute with some form of active EER group writing joint papers.

5.2.2. A stronger community in computing education research

In Finland, computing education research (CER) is a much stronger community. There have been over 30 PhD theses completed in the area since 2000, with the most important groups in Aalto University (Lauri Malmi), University of Eastern Finland (Erkki Sutinen) and in University of Turku (Tapio Salakoski).

The CER community began to form in the 1980's in the annual meetings of Finnish Society for Computer Science, where also various aspects of computing education could be discussed, including curriculum issues and research training. In 2001, Erkki Sutinen

and Tapio Salakoski initiated a national conference on Computer Science Education. It has been organised at the same site every year since, and it is now called Koli Calling, the International Conference on Computing Education Research. In 2004, it was turned into an international research conference by opening a track for *research papers*, later adding categories for technical *system papers* and *theoretical research papers*. The conference has actively solicited international participants and supported community development both in the Finnish and international CER communities (Malmi & Salakoski, 2010).

Koli is also a frequent meeting place for Nordic computing education researchers (for example, Anders Berglund and Arnold Pears from Uppsala University in Sweden have chaired the conference three times). An international doctoral consortium has often been run in connection to the conference, as from early on, many participants were PhD students in the area. Doctoral training has also been supported by other local research training courses (Berglund, Kinnunen, & Malmi, 2007), as well as international working groups, which have identified core literature in the area (Pears et al., 2007; Seidman, Pears, Eney, Kinnunen, & Malmi, 2005).

During the last 10 years more interaction has taken place between the CER community and the scattered EER community, and some experiences gathered from the CER activities have been applied in EER activities. The most significant effort was the national level Reflektori conference, organised in 2005 and 2007 in Helsinki University of Technology and in 2010 in Aalto University.

5.2.3. *Networks emerging*

In the absence of national EER networks and activities, the SEFI conference is important for bringing Finnish researchers together. After 2010 the Nordic EER networks, described below, had a strong community development role among the

Finnish EER community. The most recent development includes a national doctoral training network, STEAM-LET (Science, Technology, Engineering, Arts&Design, Mathematics and Educational Technology). Launched in 2014, it organises event and research training activities, and brings together doctoral students and their supervisors from six partner universities.

The strong role of CER in the Finnish development is explained by the interest of several groups to open a new research area in computing education, or direct their whole research activity into this area. While they are visible in our publication data set, the number of papers is low, indicating that their main activities are elsewhere. This is a likely reason for the scattering of the Finnish EER community. The future may look different, because in 2015 Tampere University of Technology opened the first Finnish tenure track professor position in EER, and this position could be expected to take a leading role. Further, two opportunities arise in 2016, when the 12th Annual International CDIO Conference is held in Turku and the SEFI Annual Conference in Tampere.

5.3 EER in Sweden

The main roots of Swedish EER can be traced to subject didactics research, to centres for teaching and learning, and to educational development projects on the national and global levels.

5.3.1. Educational development initiatives

Some notable educational development activities have contributed to building capacity and competence through their resources, activities and networks. Below, four examples follow.

During 1990-2005, the Council for Renewal of Higher Education supported development projects across higher education (Rådet för högre utbildning, 2005). Applications were rigorously reviewed and funding competitive. Jonte Bernhard, later the first professor in EER in Sweden, was granted projects (e.g. Bernhard, 2005). The focus of the council was mostly individual academics, and only towards the end of its life a program was established to fund subject matter centres with a wider mission. Uppsala University opened a centre for computer and engineering education, CeTUSS, arranging annual meetings 2004-2011. The centre also had ties with IEEE.

In 1996-1999, Linköping University (Ingemar Ingemarsson) led the NyIng project (Ingemarsson & Björck, 1999) for renewing Swedish engineering education. It took a broad approach, publishing reports on the role of engineers, structure of engineering education, recruitment – in particular of female students, the integration of human and societal understanding, development of teaching competence through critical friends, and methods for learning and assessment.

Around the year 2000, the CDIO approach for engineering education reform was founded by three Swedish universities – Chalmers, KTH Royal Institute of Technology, and Linköping University – together with Massachusetts Institute of Technology (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014; Edström & Kolmos, 2014). Since then, over 115 institutions worldwide have joined the CDIO Initiative, among them many Swedish, Danish and Finnish institutions, and the annual conference is held since 2005. Currently, the head office is at Chalmers (Johan Malmqvist). While CDIO is a community for educational *development*, much work has been published in scholarly journals, and from 2016 the annual CDIO conference has an EER track.

In 2007, a national network for engineering education was established. It was after many years of international networking that Johan Malmqvist, Kristina Edström

and others wanted an arena for engineering education development “at home”, in Swedish, and including institutions and people who had not been active in CDIO. The first conference was at KTH Royal Institute of Technology in 2008, followed by Lund University in 2009, Linköping University in 2011, Umeå University in 2013, Uppsala University in 2015, and Chalmers in 2017. The conference usually attracts some 200 participants. Following the Swedish example, a similar conference was started in Norway in 2015, with the intent to become biannual.

5.3.2. Main pathways and environments

An important origin of Swedish EER is the higher education research with a didactics focus. A first generation of researchers “crossed over” to educational research from their original discipline (e.g. physics, computer science). Some support has been available, especially since the Swedish Research Council started an Educational Sciences Committee in 2001, funding a few research projects in computer science education and engineering education. A second generation of researchers had a master degree in a discipline (i.e. engineering or computer science) and took a PhD in subject didactics, e.g. computer science education. As an intermediate step, a PhD in physics could include work with a didactical focus, studying mostly engineering students (Adawi, 2002; Ingeman, 2002). The development of dedicated career paths in didactics was strengthened through graduate schools (in e.g. mathematics education, science and technology education).

Engineering education as its own PhD subject was first established at Linköping University (first thesis by González Sampayo, 2006) and Computer science education at Uppsala University (first thesis by Berglund, 2005). More recently, EER was established as an independent research subject with its own academic environment at Chalmers (in the teaching and learning centre) and at KTH Royal Institute of

Technology (with school level teacher training and technology education research as well as a teaching and learning centre).

In parallel, EER has grown also from researchers with a base in the academic disciplines education or higher education. An early and notable example is Shirley Booth. Her thesis on learning programming (Booth, 1992) and its phenomenographic research approach (Marton, 1981; Marton & Booth, 1997) influenced many EER researchers, e.g. computer science education researchers in Uppsala.

Other entrants into EER are educational developers with a background in teaching and learning centres. One factor in the advancement of centres was faculty development, not least due to a national requirement during 2003-2010 that senior lecturers have ten weeks education in teaching and learning. Another important activity was the adaption related to the Bologna process. While much work in the vigorous and highly international community of educational developers is general for higher education, some developers in the technical universities or faculties have naturally emphasised engineering education. Several PhD theses are related to educational development in engineering education settings (Gedda, 2014; Mårtensson, 2014; Roxå, 2014).

As is evident from table 5, no university dominates the Swedish EER with regards to research output (in the studied data sets). Although the history is quite different depending on the institution, it is a landscape with several strong environments and actors, where EER is now in strong growth and fast becoming institutionalised.

6. The Nordic networks

The establishment of the Nordic network for EER is closely related to the networking on the European level. The growth of EER in Europe had created a need for more formally established communities, and already from the outset the Nordic countries

were major players on the European scene. In 2008 the European Society for Engineering Education (SEFI) formed a working group for EER (WG-EER) in conjunction with the SEFI annual conference in Aalborg, with Anette Kolmos as its first chair. The starting point for more consolidated co-operation within the Nordic countries came in early 2009, when Aalborg University and the SEFI EER working group organised a two-day EER-workshop in Aalborg.

In 2009 the research council of the Nordic Ministerial Council (NordForsk) granted funding to form two EER networks. The aim of one network was to organise a Nordic doctoral course in EER, in collaboration between Aalto University (Lauri Malmi), Uppsala University (Anders Berglund) and Aalborg University (Anette Kolmos). Facilitators were senior researchers in the Nordic countries and world-wide and the course was given in 2010 to a group of 15 doctoral students. The 15 ECTS credit course consisted of three parts, run as weeklong meetings: *Basics of EER* (Aalborg University), *EER literature* (Aalto University) and *Research methodologies* (Uppsala University). The aim was twofold: to increase the methodological competence and to encourage network building, both among the Nordic PhD-students participating in the course and among the facilitators. One participant wrote in the evaluation:

“In my view, the learning model was immersion into a community, by which I mean getting to know all the facilitators, as well as each other in the group, and spending much time together in intensive activities over an extended period. That way we could experience, directly in person, both “who’s who” and “state-of-the-art” in the emerging field of EER.”

The other network funded by NordForsk was the Nordic Network in Engineering Education Research (NNEER) co-ordinated by Linköping University (Jonte Bernhard). The aim was to arrange Nordic research seminars in EER and to support Nordic collaboration through travel grants. NNEER has held yearly 2-3 day seminars with 25-

30 participants mainly from Denmark, Finland and Sweden. In addition to invited international speakers there has been some minor participation from e.g. Norway, Estonia and Lithuania. The meetings were arranged by Linköping University in 2010, Aalto University in 2011, Aalborg University in 2012, Chalmers University of Technology in 2013, and by KTH Royal Institute of Technology in 2014. It can be noted that the institutions hosting these first meetings are also the five most active universities in terms of EER output (according to table 5). The 2016 meeting is held in Turku in conjunction with the CDIO Annual Conference.

As a result of the NNEER network and the Nordic doctoral course, ties are strengthened between people in the field, seniors as well as doctoral students. This has led to further exchange between institutional environments, to research co-operation, and to joint grant applications. The critical step is how to continue networking within the Nordic countries and connect new generations of researchers with each other, in the absence of funding for the networks.

7. Analysis and discussion

7.1. Comparing the national stories

In the national stories we see some different key characteristics in the development of EER. These are summarised in Table 7. In Denmark, compulsory staff development became the basis for growing centres at the universities as well as a strong national network including all institutions. The Danish centres were research-based from the outset, but DTU later dropped its research activities. The Danish history reveals a highly organised network at the institutional level as well as the national level. It has elements of both the horizontal and the external network – horizontal as collaboration among the institutions, external in the sense that there was external funding supporting a national

network. Although taking a more organised approach, the number of Danish publications in the selected journals and conferences do not match the Finnish level.

In the absence of compulsory staff development in the university sector, the Finnish EER activities have grown almost solely out of the disciplines. In particular, computer science education research has been the primary engine for establishing a more formalised network and EER identity. The main actors in this process were professors of computer science, combining their efforts to build a community of researchers, and promote research training in a new field. This has enabled a large number of PhD students, mostly with a background from computer science, but also from other fields, like education, to enter the field, and gain their PhD in computing education research, and taking a stronger role in the community with increasing seniority. For example, PhD graduates from this second wave of researchers have chaired the Koli Calling conference and the national STEAM-LET doctoral training network. This development is highly consistent with the CoP theory.

Although the number of Finnish authors is the highest (and only few of them in the data pool are computer scientists), it is evident that the national networking has been less organised at the level of engineering education research. As such, the Finnish national network might be characterised as a type of liberal network. From the CoP theory point of view, it was only with the establishment of the Nordic networks that the EER research could find a sense of belonging, and a joint identity.

In Sweden, the longest tradition is within the discipline-based communities, some of which also have ties to IEEE and the Finnish networks. Other roots are found in the strong teaching and learning centres and in engineering education development initiatives. More recently, specialised EER centres are emerging in the technical universities, in close relation to staff and educational development activities, and these

already dominate in terms of the more scholarly activities. The Swedish storyline is characterised by influential initiatives shaping strong relationships and much interaction, both on the national and global level, but these have mainly focused on engineering education development rather than research per se. It is also clear how networks of different scopes have been simultaneously available, i.e. the NNEER on the Nordic level, SEFI on the European level, and CDIO on the global level. These networks have interplayed, both strengthening each other and (as the time for networking of any individual researcher is limited) competing. For instance, the global activities of CDIO can be a fertile breeding ground for Nordic EER actors, but the international networking is also competing for attention when it comes to forming a Nordic scene.

We think it is clear from these narratives that initiatives have come and gone, often with little regard to long time sustainability. It seems far easier to fund new initiatives than to obtain support for maintaining long-term activities such as networks.

Table 7. Summary of national narratives.

	Denmark	Finland	Sweden
Origin	Research (EER) and staff development	Research (disciplines)	Research (disciplines), Staff development, Educational development
Dominating research identity	Engineering Education	Computer science	Higher education Subject didactics fields
National network versus individuals	Strong national network and few individuals	Individuals	Individuals Networks (development)
Institutional centres	Institutional centres for both research and development	No institutional centres	Institutional centres for both research and development

7.2. Networking in a heterogeneous field

As we have seen, Nordic EER is a markedly heterogeneous community, within as well as across the countries. We attributed the diversity mainly to the various paths into the

field, and to the different conditions for researchers. Still, when considering the need for Nordic EER it is worth noting that the higher education systems are rather similar. The Nordic countries share the democratic values and cultures that are embedded in the educational systems and define their roles in society. Strong science and engineering education has always been key for building up technological capacity and economic stability, enabling for instance the comprehensive welfare systems. Nordic higher education also has in common some challenges, both quantitative, in terms of attracting enough young people into science and technology, and qualitative, in terms of identifying and satisfying future competence profiles. This includes increasing the capacity for innovation and sustainability, both of which depend on graduates' competence in working across traditional discipline boundaries in addressing real-life problems. Given these common challenges, there is a need to strengthen the capacity of EER communities, and much can be gained from creating a joint Nordic platform.

The NNEER community is a meeting place for individuals from different subject backgrounds, with quite different organisational positions and working under different conditions – and also with different personal motivation for doing EER. Academics with a background in teaching a discipline most often have a PhD, and sometimes a career, in one of the subjects of the engineering curriculum. Others are educational developers approaching the network with a wish to augment their knowledge base, and strengthen their careers through research; some pursuing a PhD. Participants in the network have also come from research groups with focus on education. In NNEER those different actors are participants in a new community of practice, bringing with them their perspectives, understandings, cultures and identities from the communities in which they have their origin and everyday practice. Thus, at least in the three Nordic countries that we studied, the development of EER networks is

a complex process involving at least three cultures: of engineering disciplines, of subject didactics and higher education, and of educational development. To some extent those different communities must manage to approach each other and find common interest and activities where the members from different practices can cooperate.

It is likely that the background of researchers can be reflected in their conception of the aims of engineering education research. Depending on their previous experiences and identities, people may bring different interests and ideas. For instance, the researchers in a discipline are likely to have an interest in how that specific disciplinary knowledge is learned by the students and a natural starting point is classroom level research with a focus on learning the subject. They may compare educational research with research in the engineering discipline, for instance in terms of what methodology is acceptable or what status it carries. Meanwhile, educational developers have started out in a supporting role and sometimes in non-academic positions. They have often pursued a wider change agenda – often on the institutional or curriculum level, and with personal investment in the identity as change agent. This could make the distinction between educational development and educational research a relevant issue, as well as the relationship between such activities. Further, being familiar with higher education research, they may not want to label their work exclusively as EER.

When it comes to networking, members from institutional centres often have other needs than individual academics. While individual academics often first and foremost need a forum for discussion and sharing, the institutional centres have further needs as they are in the process of shaping new roles and activities and establishing new goals and standards in the field.

Despite these different backgrounds and needs, the Nordic networking has fulfilled several roles in taking Nordic EER to a next phase. First, it forms a community

in which individual researchers, some of them relatively isolated in their research endeavour, can find like-minded people and craft a joint identity. Secondly, it offers a forum for finding peers with the same research interests, to exchange ideas and knowledge, and build new collaborative actions. This has given the possibility to enhance the results and quality in research projects. Thirdly, it provides critical mass for organising research training activities, which is difficult for each single institution to achieve, and crucial for bringing new people into the field. Fourth, it has strengthened the senior capacity by forming and consolidated a steady core of key persons in the EER field, around whom new activities can grow.

From the above, it is obvious that a network cannot assemble a large number of individuals around too narrow conceptions of EER. We believe that NNEER can only function as an inspiring horizontal and to some degree an external network if it has an overall focus on development of engineering education, with plenty of room for diversity, as well as some activities supporting the consolidation of the academic infrastructures of the field.

8. Conclusions

We could clearly see that networking at the European level, particularly in SEFI, has been instrumental also in forming the Nordic network of EER. It has been a common situation to repeatedly meet one's national and Nordic colleagues a long way from home, before the relations are strong enough to enable local interaction and cooperation.

Given the inherent heterogeneity, if EER is to grow strong, it is important that its communities are inclusive and welcoming to researchers from different backgrounds. Above, we have identified the main backgrounds of EER practitioners and speculated in their diverse needs and interests. In order to learn from the complementary perspectives, it will be necessary to support dialogue and collaboration between researchers. A

sophisticated understanding of and mutual respect for the different perspectives will strengthen the field. There has been an increase in number of EER professors, associate professor positions and PhD-theses, and in this dynamic state, quality standards must constantly evolve, for instance in peer review of papers and dissertations. As an emerging field it is necessary to make room for, and have the capacity to make progress in, definitional debates.

These narratives also indicate that unless there is an arena where interaction within EER can be accommodated, there will be no identity as EER researchers, and no sense of belonging in a joint endeavour. As such the Nordic network of EER has played a key role in offering a scene for national networks, institutions and individuals to reflect themselves in. In that sense NNEER has formed a very important ground for the future. The national EER activities represent a bottom-up approach and the same does the NNEER. If it should serve as an actor with strong activities and resources, a top-down approach will also be needed to keep up the growth and momentum and becoming a stronger actor in the development of Nordic countries. The network has contributed to encouraging and educating the next generation of Nordic EER researchers, as a foundation from which the development of the research area in the Nordic countries can move in new and different directions.

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